

LBNE Reconfiguration Workshop

FD Assumptions and Cost Estimate

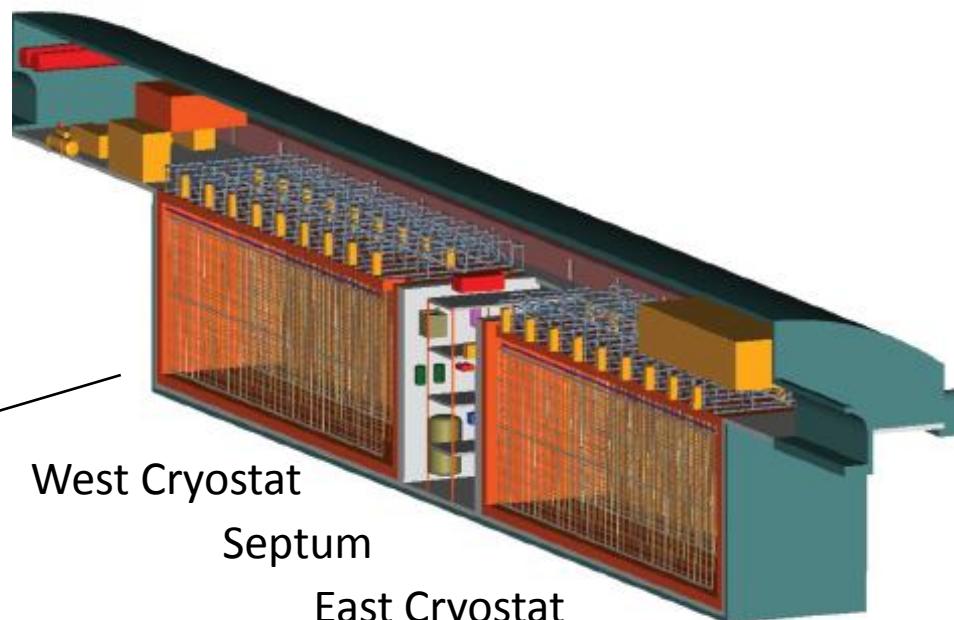
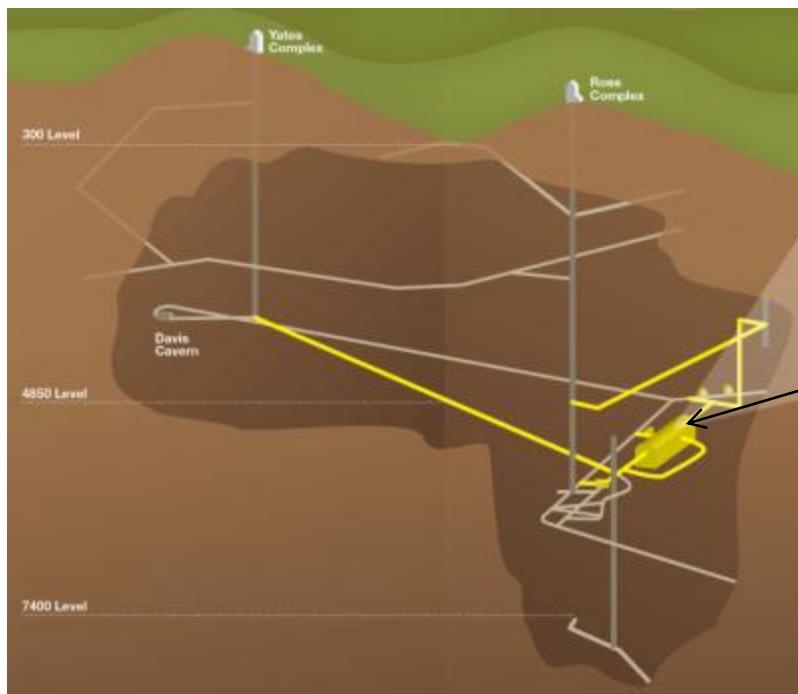
Bruce Baller

Outline

- FD reference design overview
- Assumptions
- Cost estimate sources
- Scaling methodology
 - Examples of simple (detector) & complex (cryogenic plant) scaling
- “Design” assumptions
- Photon detection for surface options?
- Configuration and cost summary
- Contingency
- Summary

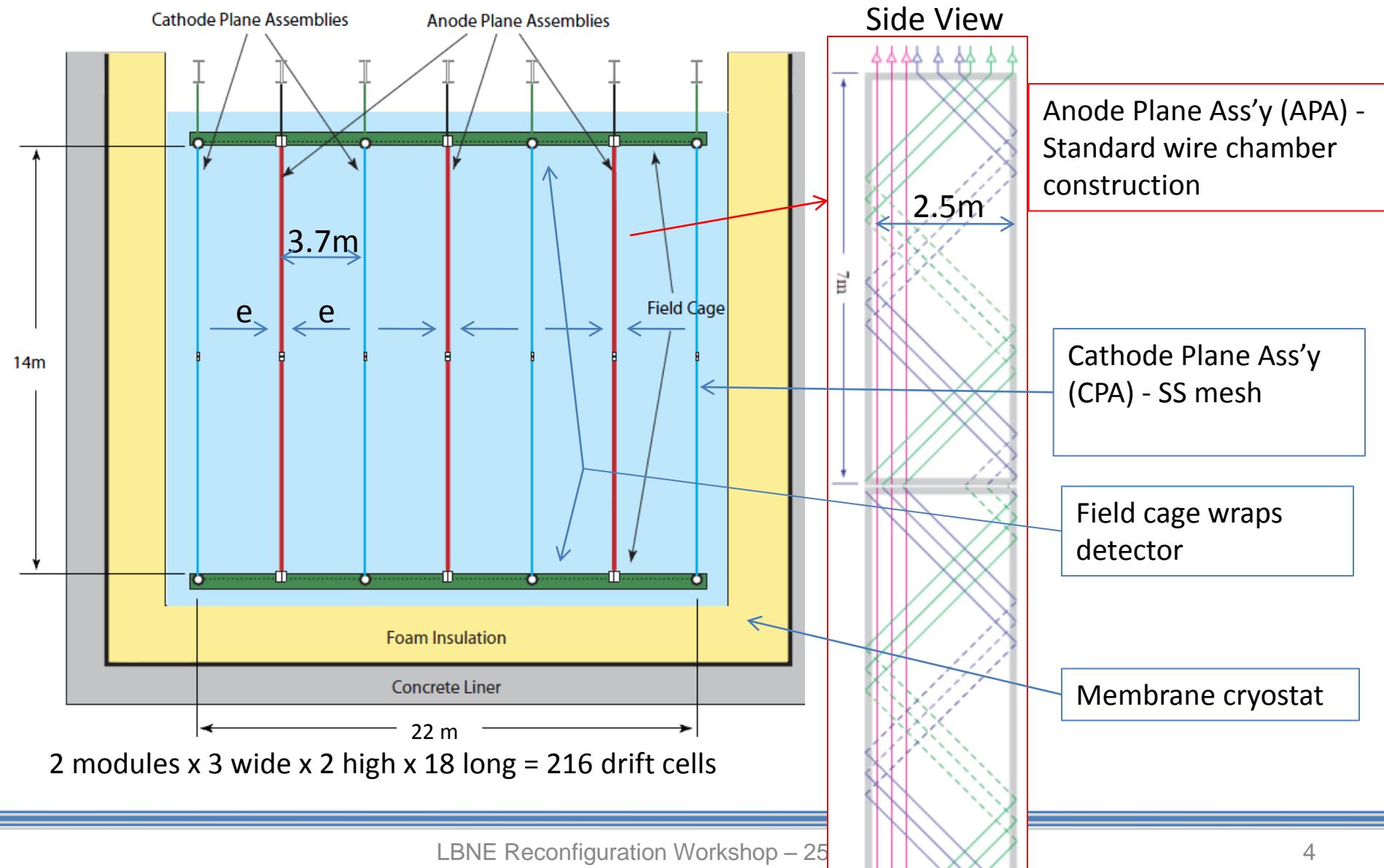
FD Reference Design

- 33 kton fiducial mass Liquid Argon (LAr) detector located 4850L underground in Lead, SD
- Detection capabilities: accelerator and atmospheric neutrinos, nucleon decay, neutrinos from supernova occurring in the galaxy

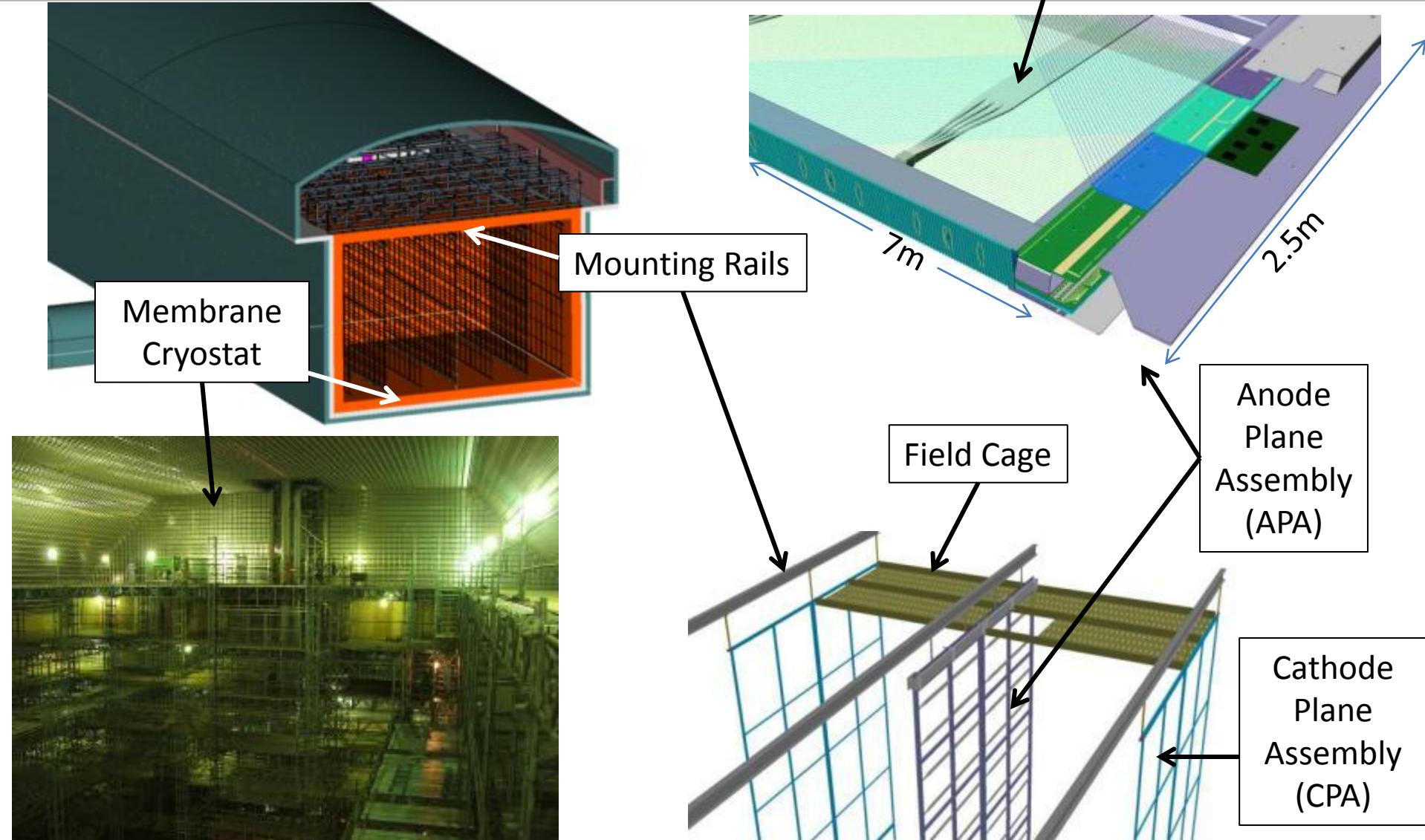


FD Reference Design

Beam's Eye View

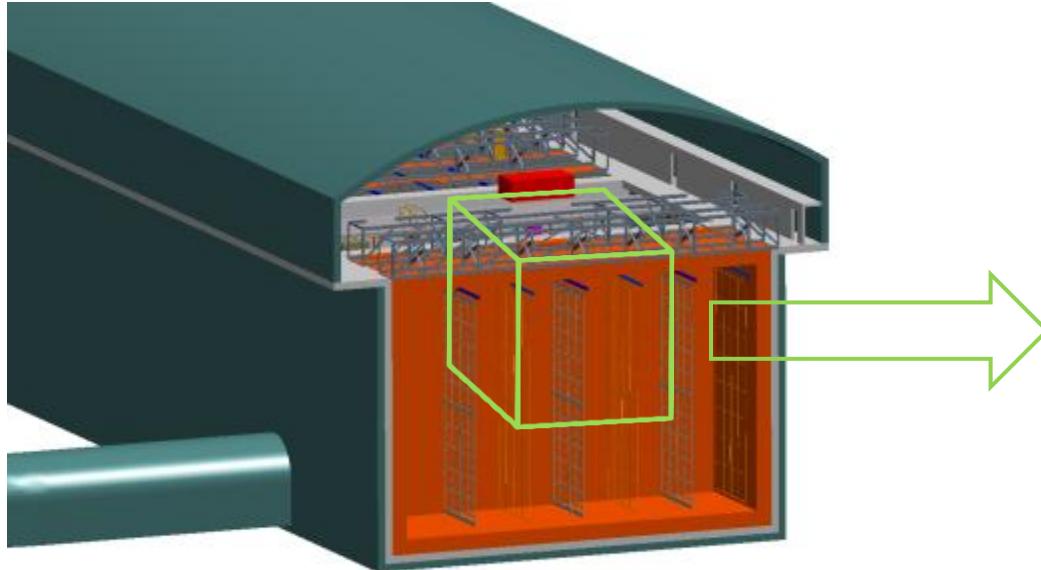


Detector Overview

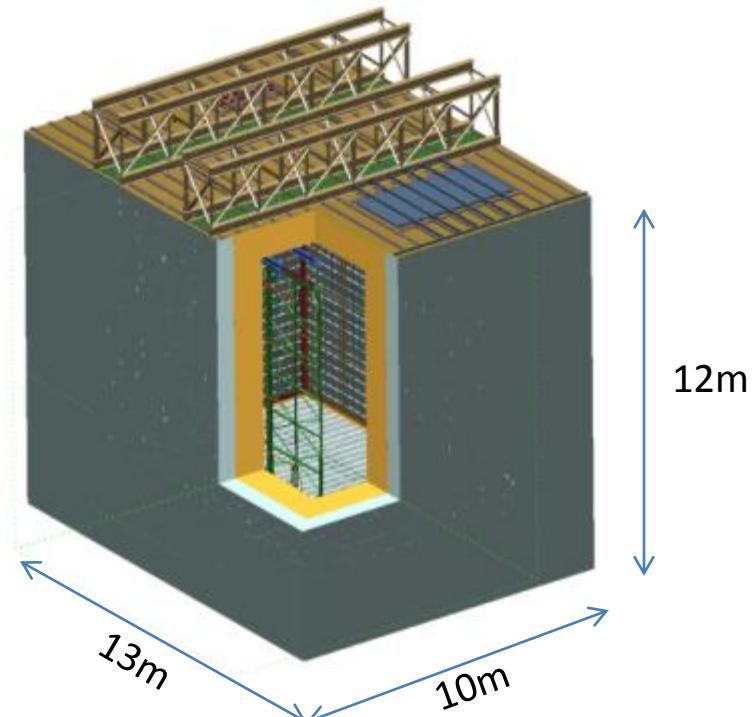


1 kton Prototype - \$24M

- LAr1 represents a portion of one detector module at a scale sufficient to gain confidence in the success of the full size detector. Many features of LAr1 are at a 1:1 scale



2 modules x 3 wide x 2 high x 18 long
= 216 drift cells

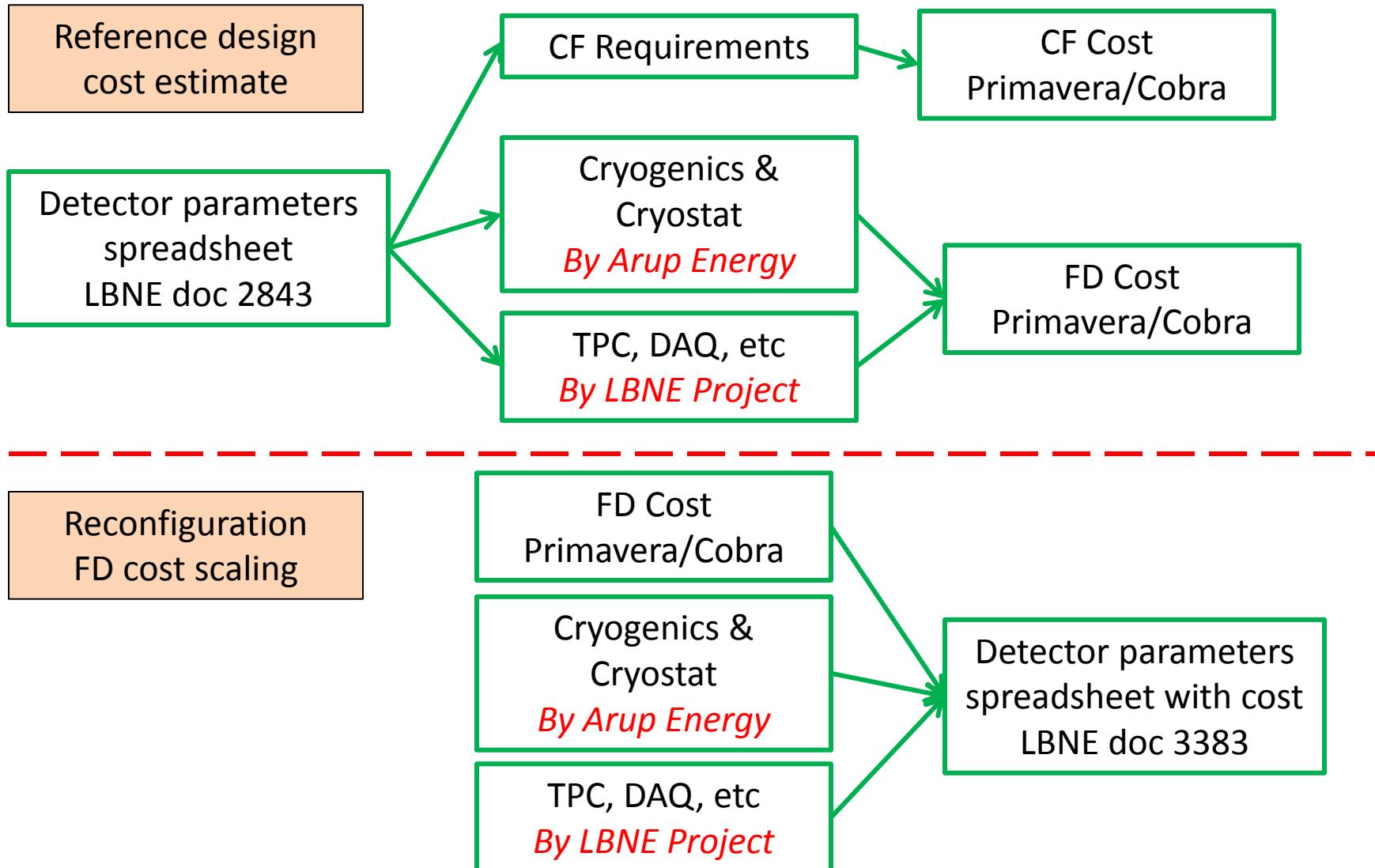


1 module x 1 wide x 1 high x 3 long
= 3 drift cells

Assumptions

- Fixed costs we would incur in any scenario
 - Design, tooling, administration (e.g. bid solicitation)
 - Project management CD-0 → CD-3 (\$10M)
 - 35 ton membrane cryostat prototype (\$3M)
 - Installation prototype, above-ground infrastructure
- Construction costs scale with relevant detector parameters
 - TPC, DAQ and photon detection
 - Number of components
 - Cryostat and cryogenics
 - Surface area and cryo plant capacity (kW)
 - Below-ground infrastructure
 - Number of components, cryostat floor area, number of cryostats
 - Installation and checkout
 - Number of components, number of cryostats

Design and Cost Estimate Sources



Arup Energy

- Design experience on ~20 LNG projects
- 9 projects with membrane cryostats
 - 2003 – 2010
- Reference design has 30% risk based contingency

Cryogenic and Cavern Storage Experience

Arup experience on conceptual studies and engineering of cryogenic and cavern storage projects is tabulated below.

Sengkang LNG Tank Detailed Design

Sulawesi, Indonesia

Client: Energy World International

Conceptual engineering design for the ACLNG tank solution and detailed engineering for a membrane LNG tank of 130,000 m³ capacity.



Offshore LNG Liquefaction Facilities and Receival Terminals Studies

Gulf-of-Mexico, Australia, Mediterranean, Atlantic, South China Sea

Clients: Various

Conceptual and FEED solutions for offshore LNG storage in 9% Nickel, concrete and membrane lining systems. In addition to LNG storage engineering development additional consideration was given to transportation effects. Execution plan, cost and schedule estimates were prepared.



Detector Parameters - *simplified*

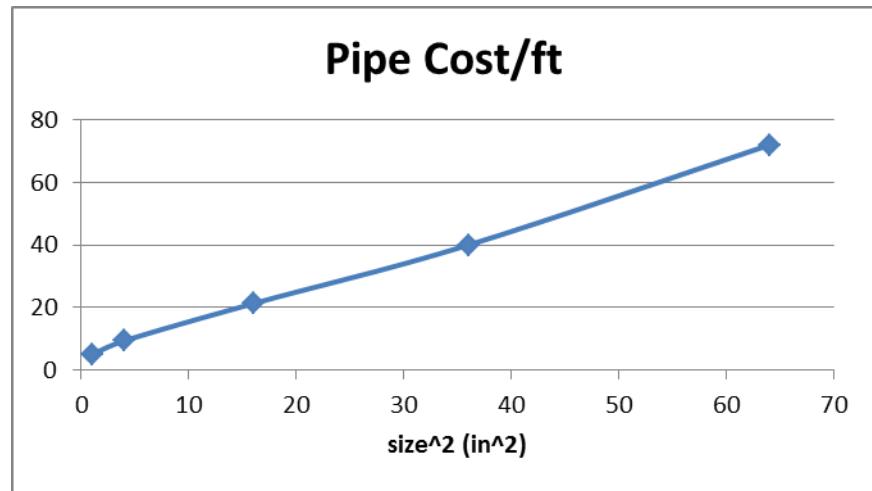
- Detector length = (num longitudinal APAs) x (APA length)
 - Reference design length = $18 \times 2.5\text{m} = 46\text{m}$
- Detector fiducial length = detector length – 1.5m
- Cryostat length = detector length + (near end allowance for utilities) + (far end allowance for access hatch)
 - Reference design length = $46\text{m} + 0.5\text{m} + 2.5\text{m}$
- Pit length = cryostat length + 2 x insulation thickness + 2 x concrete liner thickness
- Calculate numerous derived parameters (~200)
 - Num APAs, num CPAs, cryostat volume, cryostat surface area, excavated volume, fiducial mass, ...

Scaling

- Scaled costs include Direct + Indirect + Contingency (DIC)
- Select relevant scaling quantities or parameters
- Calculate unit costs using reference design parameters
 - Examples
 - TPC scaling
 - APA = \$90k each w/o electronics
 - Field cage = \$200/m²
 - Cryostat scales by surface area
 - Cryostat = \$4.9k/m²
 - Scale costs for the particular detector configuration chosen

Cryogenic Piping Unit Cost Scaling

- M&S: Pipe and valve material cost \sim size 2 \sim flow rate \sim cryo plant capacity
 - Online pipe quotes \rightarrow
 - Small fixed cost



- Labor: Assume labor cost is independent of component size
 - Arup cost estimate for VIP installation \rightarrow
 - Material handling labor > welding labor
 - 100% fixed cost

BID ITEM = 307010		Land Item	SCHEDULE: 1	
Description = Cavern Equipment and Pipe		Unit =		
10300	Install Pipe: Pipe in Cavern	Quan:	173.00	M
SDP-1	Pipe Install Crew	173.00	CH	Eff: 100.00 Prod: 8.000
8LFORK	Fork Lift	1.00	173.00	HR 43.060
8LIFTS32	Scissor Lift 32'	1.00	173.00	HR 29.700
8MNVENTFAN	Aux Vent Fan - 40 HP	1.00	173.00	HR 13.360
8TMC	Mechanic Tool Box	1.00	173.00	HR 23.700
8TMCH	Mechanics Truck	2.00	346.00	HR 23.700
8WLD350	Welder - 350 Amp	3.00	519.00	HR 6.850
8ZGL4	Light Plant - 4 Lights	1.00	173.00	HR 5.350
8ZGP	Power Drop	1.00	173.00	HR 19.750
8ZTE	Power Tools - Electri	5.00	865.00	HR 10.000
8ZWLD	Welding Machine	3.00	519.00	HR 8.500
LUPIPEF	Pipe Foreman	1.00	173.00	MH 31.980
LUPIPELAB	Pipe Fitter Lab	3.00	519.00	MH 27.790
LUPIPES	Pipe Skilled	3.00	519.00	MH 31.980
LUPIPEW	Pipe Welder	3.00	519.00	MH 31.980
\$144,115.17	10.0000	MH/M	1,730,000.00	MH [307.23]
1.0000	Units/H		8.0000	Un/Shift *
			0.1000	Unit/M

Depth Scaling

N2 Compressors in surface building

20m

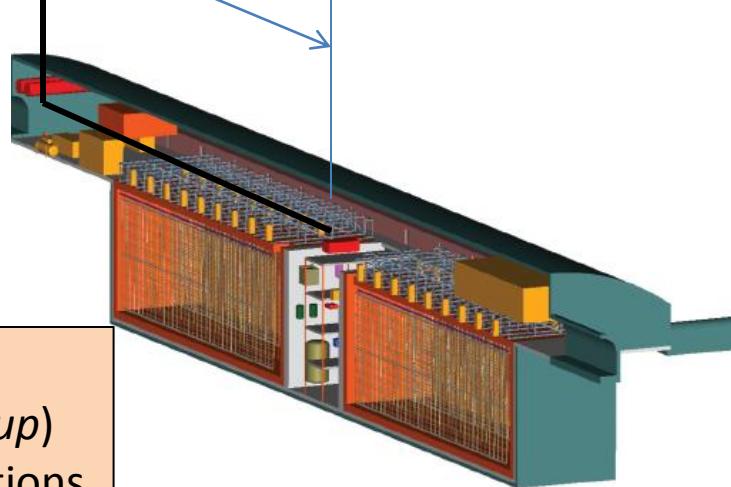
Detector depth
= 0 for surface options

8" Vacuum insulated SS pipe Ar supply
6" SS vent line
3 x 8" steel nitrogen gas lines
~\$12k/m installed

UG labor cost = 1.3 x surface labor

Material transport to cavern

Reference design: \$2M cryogenics (Arup)
Scale by 20% x unit cost for surface options



“Design” Assumptions

- 1 kton prototype
 - Includes \$24M for 17 kton and 34 kton options
 - \$0M for 5 kton options
- Cryo plant capacity set so that:
 - Margin ~ 40% for below ground options (argon gas reliquefaction)
 - Margin ~ 20% for surface options (LAr filling)
- Number of cryostats
 - Assume 2 for 17 kton and 34 kton options, 1 for 5 kton options
 - Cost above ground storage tank for 5 kton options (\$14M)
- Assume 1 standby refrigerator for all options
 - Standby refrigerator cost = \$5M (45 kW) - \$10M (100 kW)
- Reduced the number of LAr filter regeneration systems for each cryostat from 3 (reference design) to 1
- Adjusted number of LAr pumps and pump rate to achieve a maximum turnover of 1 volume change every 5.5 days
- Space charge distortions for 2.5m drift (cm-scale) are acceptable for surface options
- CD-3 → CD-4 PM costs scale by estimated project duration
- Detector drift cell configurations chosen to equal 5, 17 and 34 kton $< \pm 0.1$ kton

Photon Detection System

- Cost \$3.6M (5 kton) - \$11M (34 kton)
- Photon detection used for
 - Non-accelerator physics studies
 - Cosmic ray trigger → calibration
- DAQ: continuous (UG), external trigger (surface)
 - Beam spill signal ok for neutrino oscillation physics
 - Calibration possibilities
 - Cosmic ray photon detection system
 - Cosmic ray external tracking/trigger
 - Laser system
 - Cosmic ray random trigger → assume this
- Set cost to \$0 for surface options

Detector Options & Costs

Configuration	Fid Mass (kton)	Level	Drift (m)	DIC (\$M)	Cryo Plants	Location
1x2Hx3Wx10L	5	0	2.3	\$132	2 x 45 kW	SURF, Ash River, Soudan
1x2Hx2Wx9L	5	27L	3.65	\$143	2 x 60 kW	Soudan
1x2Hx2Wx9L	5	4850L	3.65	\$149	2 x 60 kW	SURF
2x2Hx4Wx12L	17	0	2.38	\$243	3 x 50 kW	SURF, Ash River, Soudan
2x2Hx3Wx10L	17	27L	3.63	\$257	3 x 70 kW	Soudan
2x2Hx3Wx10L	17	4850L	3.63	\$263	3 x 70 kW	SURF
2x2Hx4Wx23L	34	0	2.42	\$350	3 x 75 kW	SURF, Ash River, Soudan
2x2Hx3Wx18L	34	27L	3.89	\$354	3 x 100 kW	Soudan
2x2Hx3Wx18L	34	4850L	3.89	\$359	3 x 100 kW	SURF

Preliminary check done by Barry Norris, (FNAL), Jack Fowler
(Duke) and Russ Rucinski (FNAL)

Scaled Cost Breakdown & Contingency

Example: 34 kton 4850L

WBS	Name	Scaled DIC k\$	Scaled Cont %
130.05	LAr-FD	\$359,338	36%
130.05.01	LAr Project Management	\$14,018	18%
130.05.02	LAr Cryogenics & Cryostat	\$234,105	36%
130.05.02.01	LAr Cryogenics System - Conceptual Design	\$1,084	12%
130.05.02.02	LAr Cryogenics System - Preliminary Design	\$3,492	41%
130.05.02.03	LAr Cryostat 35t Prototype - Purity	\$2,864	21%
130.05.02.04	LAr Cryogenics System - Final Design	\$5,453	39%
130.05.02.05	LAr Cryogenics System - Construction	\$156,260	50%
130.05.02.06	LAr Cryogenic Fluids Procurement	\$51,937	10%
130.05.02.07	LAr Cryogenics System - Checkout	\$1,008	69%
130.05.02.08	LAr Cryogenics Management	\$12,007	9%
130.05.04	LAr TPC	\$49,918	38%
130.05.05	LAr Detector Monitoring & Control	\$5,962	53%
130.05.06	LAr Installation & Commissioning	\$20,309	54%
130.05.07	LAr Photon Detector	\$11,057	38%
130.05.09	Lar 1kt Prototype	\$23,968	32%



Summary

- Scaled cost estimates derived from well-reviewed FD reference design
- Cryogenics construction contingency inflated from 30% to 50%
- Scaling and “Design” assumptions seem credible
- Calibration system for surface operation needs more thought